(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 245 508 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication of patent specification: **05.01.94** (51) Int. Cl.5: **G06K 9/66**, G06F 15/18

(21) Application number: **86906452.7**

(22) Date of filing: **30.10.86**

(86) International application number:
PCT/JP86/00551

(87) International publication number:
WO 87/02805 (07.05.87 87/10)

(54) **HIERARCHICAL DATA PROCESSING SYSTEM.**

(30) Priority: **02.11.85 JP 245298/85**

(43) Date of publication of application:
19.11.87 Bulletin 87/47

(45) Publication of the grant of the patent:
05.01.94 Bulletin 94/01

(84) Designated Contracting States:
DE FR GB NL

(56) References cited:
JP-A-52 127 132
JP-A-53 110 334

BIOL. CYBERN., vol. 55, no. 1, October 1986, pages 5-15, Springer-Verlag; K. FUKUSHIMA: "A neural network model for selective attention in visual pattern recognition"

(73) Proprietor: **NIPPON HOSO KYOKAI**
2-1, Jinnan 2-chome
Shibuya-ku
Tokyo 150(JP)

(72) Inventor: **FUKUSHIMA, Kunihiko**
Nippon Hoso Kyokai Techn. Research Lab.
10-11
Kinuta 1-chome Setagaya-ku Tokyo 157(JP)

(74) Representative: **Lehn, Werner, Dipl.-Ing. et al**
Hoffmann, Eitle & Partner,
Patentanwälte,
Postfach 81 04 20
D-81904 München (DE)

EP 0 245 508 B1

DENSHI, TSUSHIN GAKKAI ROBUNSHI, vol. 69D, no. 6, June 1986, pages 993-1003; K. FUKUSHIMA: "A neural network model for the mechanism of selective attention in visual pattern recognition"

IEEE Transactions on Systems, Man, and Cybernetics, Vol. SMC-13, No. 5, (1983), K. Fukushima et al (Neocognitron: A Neural Network Model for a Mechanism of Visual Pattern Recognition)

IEEE Transaction on Systems, Man, and Cybernetics, Vol. SMC-13, No. 5 (1983), Y. Hirai. (A Model of Human Associative Processor (HASP)) P.851-857.

Description

Technical Field

The present invention relates to a hierarchical information processing system for processing an information in a cascade of successively arranged plural information processing layers in each of which plural nonlinear elements are two-dimensionally arranged, particularly, provided with an autoassociative recall type high grade associative memory function by which a pattern consisting of characters and figures excessively distorted in shape or excessively shifted in position, or accompanied with expansion or reduction can be readily and accurately recognized, as well as noise contained therein can be removed or defected portions thereof can be interpolated.

Technical Background

As for a network required for recalling or recognizing a complete pattern on the basis of an incomplete pattern, various kinds of autoassociative recall type associative memory networks have been conventionally proposed. However, most of these conventional associative memory networks could be satisfactorily operated only when an input pattern did not only consist of a previously learned training pattern, but also the former completely coincided with the latter in size, shape and position. Although an associative memory system such as those employing an autocorrelation function accepting only the shift in position of the input pattern has been conventionally proposed, this conventional system also was completely impotent with regard to the change in size and the distortion in shape of the pattern.

The present applicant has already disclosed a pattern recognition system called as "neocognitron" in the specifications of Japanese Patent No. 1221756 (Japanese Patent Application Publication No. 58-53790) "A pattern recognition system" and Japanese Patent No. 1279063 (Japanese Patent Application Publication No. 60-712) "A pattern recognition equipment", which system is provided with an ability for correctly recognizing a pattern without any affection of those mentioned above, that is, the shift in position, the distortion in shape, the change in size and the like of the input pattern. However, these disclosed system and equipment relate to no more than the pattern recognition restricted within the above-mentioned version, and hence have not yet been provided with such an ability that an information regarding a phenomenon is derived from incomplete or ambiguous informations with regard thereto by the autoassociative recall, that is, the associative memory function required for attaining a further higher grade pattern recognition.

On the other hand, the present applicant has also disclosed, as for a system provided with the aforesaid associative memory function, a hierarchical information processing network in Japanese Patent Application Laid-open Publication No. 59-163679 "A hierarchical information processing network", which network is provided with an ability such that similar patterns resembling a previously learned training pattern are successively selected in turn from plural input patterns, or, a complete pattern is recalled from an incomplete input pattern or an input pattern obscured by noise. This system is considered to represent the closest prior art. However, this hierarchical information processing network has not yet also been provided with the aforesaid ability for processing the shift in position and the deformation in shape of the input pattern, similarly as the conventional associative memory systems which have been proposed everywhere.

Disclosure of the Invention

An object of the present invention is to remove the above-mentioned various shortcomings, and to provide a novel hierarchical information processing system in which the above-disclosed hierarchical information processing network is offered with an ability such that the pattern recognition can be achieved without any affection of considerable defects such as the deformation in shape, the change in size and the shift in position of the input pattern, as is different from the aforesaid "neocognitron", but with a higher grade autoassociative recall type associative memory function and further with a faculty of segmentation.

The invention is set out in claim 1.

Accordingly, in the hierarchical information processing system of the present invention, for achieving the information processing mainly through the aforesaid hierarchical information processing network:

both of afferent signal paths extended upwards from lower order stages on the pattern input side to higher order stages on the recognition output side and efferent signal paths extended downwards from higher order stages to lower order stages on the contrary are provided;

an input information supplied to the lower order stages is successively transmitted to the higher order stages through the afferent signal paths, as being successively processed in each of plural cell-layers of successive order stages, meanwhile, in the direction opposite thereto, an output derived from the higher order stages is fed-back to the lower order stages through the efferent signal paths;

once an output response has been derived

from the higher order stages, according to the action of the efferent signal transmitted from the higher order stages to the lower order stages, the afferent signal paths contributing to cause the output response in the higher order stages and the information processing processes belonging thereto are affected by an excitatory effect, while the remaining efferent signal paths and the information processing processes belonging thereto are affected by an inhibitory effect;

the ability of the pattern segmentation, that is, the distinction of components of a specified pattern from the remainder is offered by selectively extracting only the information relevant to the specified pattern from plural patterns supplied to the lower order stages on the input side; or

a complete pattern can be associatively recalled from an incomplete pattern by removing noise contained therein or by interpolating missing portions thereof.

Brief Description of the Drawings

Fig. 1 is a block diagram showing an example of hierarchical structure of an neural network model employed for a hierarchical information processing network of the system according to the present invention; and

Fig. 2 is a block diagram showing an example of spatial connection between network elements in a part of the hierarchical structure as shown in Fig. 1.

Best Mode for Carrying out the Present Invention

Generally speaking, when a composite pattern consisting of a combination of more than two patterns is presented, our human being is able to observe one of these patterns at a time with attention in order and, as a result, to individually recognize what is each of these patterns, as well as to effect the aforesaid pattern segmentation. Besides, at the same time, even when the pattern observed with attention is deteriorated by defects or noise, our human being is able to associate a complete pattern by interpolating those defects or by removing the noise. In this connection, it is not required that the presented pattern completely coincides with the previously learned training pattern in shape or in size. Our human being is provided with an ability for completing the original, even when the shape thereof is somewhat distorted or the size thereof is changed, by directly interpolating defects of the distorted pattern or by directly removing noise therefrom, and further by effectively utilizing a slight trace remaining in the defective portion of the attended pattern. The information processing system of the present invention has been proposed on the basis of the neural network model provided for realizing this ability of our human being.

A preferred embodiment of the present invention will be described in detail hereinafter by referring to the accompanying drawings.

An embodiment based on a multilayered network consisting of network elements arranged in layer state will be described hereinafter. However, as for the concrete realization, it is enough to carry out the same algorithm, so that it is not necessary at all to restrict the embodiment to be described within the structure of the above multilayered network.

In general, the neural network model used for the pattern recognition equipment is composed of a combination of plural cell-layers in which plural cells are arranged in multilayer state, and hence the hierarchical structure as shown in a block diagram of Fig. 1 is exemplified as of four layers. In this block diagram, a circular mark ○ indicates a cell. Although each of the cell layers actually contains plural cells, plural cells of each kind are represented by only one cell in Fig. 1. Besides connections as indicated by single or double lines in Fig. 1 exist between these cells, the single line showing the existence of one-to-one connection between heterogeneous cells corresponding to each other, while the double line showing the existence of converging or diverging connection between two groups of cells.

In this regard, the afferent signal is processed in the same structure as that of "neocognition" as described in the specifications of Japanese Patents Nos. 1221756 and 1279063. In this structure, a feature-extracting cell u_s (including u_{s1}, u_{s2}, u_{s3} and so forth) extracts the feature of the pattern in association with an inhibitory cell u_{sv}. Hence, only when a specified feature exists in a specified portion of the input cell-layer, an output response is derived therefrom. On the other hand, a feature-integrating cell u_c extracts the same feature also. However, this cell u_c receives output responses respectively derived from plural feature-extracting cells u_s positioned in different portions of the input cell layers, so that, even when the position for indicating the same feature in the input layer is shifted to some extent, the feature-integrating cell u_c itself continues to extract the same feature. An aspect of spatial interconnections between these cells u_s and u_c is shown in Fig. 2.

As described above, the afferent signal gradually integrates local features into a global feature, as the extraction and the integration of features are repeated in each layer of the multilayered network, and hence, the feature-integrating cell u_c inthe final layer globally observes the feature extracted from the whole input layer, namely, the input pattern, and, as a result, what is the input pattern can be

recognized.

In other words, an output response of the final cell-layer is derived from only one feature-integrating cell u_c corresponding to the category of the input pattern in response to what is the category concerned. In these processes of the extraction and the intergration of features, the shift in position of these features from each other is gradually accepted, and hence, the accurate pattern recognition can be realized in the final cell-layer without any affection of shift in position as well as distortion in shape of the pattern supplied to the input cell-layer.

As for the above mentioned processing of the afferent signal, the same structure of network as that of "neocognitron" as disclosed in the specification of Japanese Patents Nos. 1221756 and 1279063 can be employed.

In contrast with the above, the efferent signal is transmitted from the higher order cell-layers to the lower order cell-layers through a feature-indicating cell w_s and an intergrative feature-indicating cell w_c which make pairs with the feature-extracting cell u_s and the feature-integrating cell u_c as described above, respectively. That is, the efferent signal is transmitted downwards through the path just opposite to that of the afferent signal transmitted upwards.

In order to attain the above situation, it is sufficient that the coefficients of connections between each cell are arranged such that the efferent signal derived downwards from the feature-indicating cell w_s is transmitted through the path just opposite to that through which the afferent signal is transmitted toward the feature-extracting cell u_s paired therewith. In this regard, a feature-indicating inhibitory cell w_{sv} is an auxiliary cell corresponding to an inhibitory cell u_{sv} for inhibiting the afferent signal. As for the structure concerning these cells, substantially the same structure as that of the hierarchical information processing network as disclosed in Japanese Patent Application Laid-open Publication No. 59-163679 can be employed.

However, the path of the efferent signal transmitted downwards from the integrative feature-indicating cell w_c to the feature-indicating cell w_s in the preceding cell-layer cannot be individually set up for the convenience of the efferent signal concerned. It is because the feature-integrating cell u_c paired with the integrative feature-indicating cell w_c is arranged so as to derive an output response, whenever any one of plural feature-extracting cells u_s in the preceding cell-layer derives an output therefrom. So that, the efferent signal divergently derived from the integrative feature-indicating cell w_c is transmitted to plural feature-indicating cells w_s, these cells w_s further receiving a signal operating as a gating signal from the feature-extracting cell u_s corresponding thereto and hence being arranged to derive an output only when the signals are derived from both of the feature-extracting cell u_s and the integrative feature-indicating cell w_c thereto. According to this arrangement, as for the efferent connection from the integrative feature-indicating cell w_c to the feature-indicating cell w_s also, the efferent signal can be transmitted downwards through the same path as the afferent signal paired therewith and transmitted upwards from the feature-extracting cell u_s to the feature-integrating cell u_c.

On the other hand, the efferent signal is not only affected by the afferent signal as mentioned above, but also affects the afferent signal on the contrary. That is, the fact that an output is derived from one of the feature-integrating cells u_c in the highest order stage of the network means that the pattern belonging to the category corresponding to the feature-integrating cell u_c concerned has been recognized through the network concerned. In this situation, the efferent signal transmitted downwards from the feature-integrating cell u_c in the highest order stage is arranged so as to be supplied only to the cells directly related to the recognition of the pattern recognized in this situation. In this regard, in a situation where the input pattern supplied to the lowest order input stage is a composite pattern consisting of plural patterns, outputs of the intermediate stage in the afferent signal path are not necessarily derived only from the cells corresponding to the feature of the pattern recognized through the final stage, but also derived from the cells corresponding to the features of the remaining patterns. In order to leave only the outputs derived from the cells corresponding to the feature of the finally recognized pattern and to erase the outputs derived from the remaining cells, the feature-integrating cell u_c is provided with an operational effect similar to the biological "habituation", so as to gradually lower the gain between the input and the output thereof with the lapse of time. However, in conjunction therewith, a signal for forcibly recovering the lowered gain is arranged to be supplied to the feature-integrating cell u_c from the integrative feature-indicating cell w_c paired therewith. As a result, the feature-integrating cell u_c belonging to the path, through which the efferent signal is transmitted downwards, is affected by an excitatory effect, and hence the lowering of the gain is not caused.

The output of the integrative feature-indicating cell w_c does not only affect the feature-integrating cell u_c upwards corresponding thereto with the excitatory effect, but also affects the feature-extracting cell u_s. In this regard, the fact that, although an efferent output is derived from an intergrative feature-indicating cell w_c, any afferent output has not been derived from the feature-integrating cell u_c

corresponding thereto means that the feature of the pattern, which should be taken charge of by the feature-integrating cell u_c concerned, fails to be extracted thereby. In this situation where, although the efferent output is derived from the integrative feature-indicating cell w_c, any afferent output is not derived from the feature-integrating cell u_c corresponding thereto, this situation concerned is detected by a threshold controlling cell w_{cx}. When an output is derived from the threshold controlling cell w_{cx} as a result of this detection, this output is operated so as to weaken the affection of the inhibitory, namely, negative signal supplied to the feature-extracting cell u_s, and hence the selectivity of the feature extraction effected by the feature-extracting cell u_s concerned is weakened. In short, the feature-extracting cell u_s supplied with the output of the threshold controlling cell w_{cx} is forced to respond to the feature of the pattern which should be originally extracted by the feature-extracting cell u_s concerned, even if the feature is incomplete to some extent. In other words, the feature-extracting cell u_s is forced to be operated similarly as, when our human being observes a blurred character, our human being extracts the components of the character concerned which should exist in the blurred portions thereof with the help of the slight traces left in the blurred portions thereof.

Once the feature has been extracted by the feature-extracting cell u_s on the basis of at least left slight trace thereof as described above, the efferent signal is resulted to be transmitted further downwards through the feature-indicating cell w_s corresponding to the feature-extracting cell u_s concerned.

Under the repetition of the above-mentioned operation, only the components of the pattern which is recognized through the response of the feature-integrating cell w_c in the final stage is resulted to appear in the cell-layer in which the integrative feature-indicating cell w_{co} of the initial stage exists. Moreover, in this situation, the efferent signal is resulted to be transmitted downwards through the same path as the afferent signal corresponding to the efferent signal concerned. So that, even if the input pattern has been deformed from the previously learned training pattern, only the components corresponding to the recognized pattern appear in the cell-layer, in which the integrative feature-indicating cell w_{co} of the initial stage exists, in the just same form as the deformed input pattern. Moreover, even if defected portions exist in this deformed input pattern, the interpolation which naturally corresponds to the deformed input pattern is applied onto those defected portions, and hence it is resulted that a deformed but indefectible pattern appears in the cell-layer in which the integrative feature-indicating cell w_{co} of the initial stage exists.

In this regard, a signal x derived from a maximum detector MAX which is presented in the right end portion of Fig. 1 is transmitted to all of the feature-extracting cells u_s, only when no output is derived from any of the feature-integrating cells u_c of the final stage. This signal x lowers the selectivity of the response of the feature-extracting cell u_s similarly as the aforesaid output of the threshold controlling cell w_{cx}, and hence, even if the feature of the input pattern is incomplete, the feature-extracting cell u_s is arranged so as to extract the incomplete feature concerned. As a result, any one of the plural patterns supplied as the input is recognized in the first place.

As described above, only a part of the input composite pattern which corresponds to the specified one pattern of the plural patterns contained therein is separated therefrom, so as to appear in the cell-layer in which the integrative feature-indicating cell w_{co} of the initial stage exists, the category of the separated pattern concerned can be determined, namely, recognized in response to which one of the plural feature-integrating cells u_c of the final stage from which one the output has been derived. In short, the segmentation in the pattern recognition can be effected. In this respect, if the output of the cell-layer in which the integrative feature-indicating cell w_{co} of the initial stage exists is regarded as an autoassociative recall type associative output, an associative memory network which is never affected by the deformation and the positional error of the input pattern can be regarded to be realized.

In this situation where any one of the plural input patterns has been recognized, for setting about the recognition of another pattern thereof, it is enough to stop the flow of the efferent signal for an instant. The feature-integrating cell u_c is arranged such that, when the facilitating signal derived from the integrative feature-indicating cell w_c corresponding thereto is stopped, the gain thereof lowered by the affection of the effect of "habituation" is restored, meanwhile the gain thereof forcibly increased by the affection of the facilitating signal is lowered in the just same manner as by the fatigue in response to the extent of the forcible increase of the gain. As a result, after the above instant stop of the efferent signal, the previously recognized components of the input composite pattern has been made to hardly pass through the afferent signal path, and hence another pattern different from the initially recognized pattern is resulted to be recognized. Accordingly, it is possible that various kinds of operations such as the pattern recognition, the segmentation, the association and the like as described above is successively carried out as for one after another of the

plural input patterns.

With regard to the extents of the modifiable synaptic connections as indicated in Figs. 1 and 2, it is enough to vary the extent of the afferent connection by means of the autolearning as disclosed in the specification of Japanese Patent No. 1279063, as well as to vary the extent of the efferent connection in association with the corresponding afferent connection by means of the method similar as disclosed in Japanese Patent Application Laid-open Publication No. 59-163679.

In this regard, various kinds of marks respectively indicating various kinds of connections and synapses together with the operations thereof will be commented hereinafter in a lump.

= converging or diverging connection between two groups of cells

- one-to-one connection between two cells corresponding to each other

→ unmodifiable excitatory (positive)synapse

-▷ modifiable excitatory (positive) synapse

⊣ unmodifiable inhibitory (negative) synapse

-□ modifiable inhibitory (negative) synapse

-○ heterosynaptic facilitating signal for controlling gain of target cell

-◁ inhibition weakening signal for controlling selectivity of target cell

Industrial Applicability

The segmentation in the pattern recognition is extremely difficult to be applied particularly as for the modified input pattern such as handwritten characters, and hence has been conventionally effected, for instance, with the help of parallel crosses previously printed on manuscript papers.

In this regard, according to the present invention, as for any possibly deformed pattern, the segmentation can be correctly effected without the affection of the deformation concerned.

On the other hand, with respect to the associative memory equipment, that of the conventional system has been hardly prepared so as to be satisfactorily operated, even if the positional error, the deformation, the expansion, the reduction or the like is contained in the input pattern, meanwhile that of the system according to the present invention can be prepared so as to be correctly operated without the affection of the positional error, the deformation, the expansion, the reduction or the like.

This situation can be realized by the fact that the information processing network employed for the hierarchical information system according to the present invention is newly provided with the efferent signal path together with the conventional afferent path and that such an operation is prepared between the afferent and the efferent signals, so as to facilitate the flow of those signals corresponding to each other, as well as to attenuate the flow of those signals not corresponding to each other.

As is apparent from the mentioned above, according to the hierarchical information processing system of the present invention, it is possible to realize a novel pattern recognition equipment provided with an extremely higher grade faculty being quite different from the conventional one such that the segmentation is effected by separating only a portion corresponding to one specified pattern from plural input patterns and that the autoassociative recall type associative memory is effected for interpolating defected portions of the input pattern. Besides, in this situation also, the similar faculties as of "neocognitron" as disclosed in the specifications of Japanese Patents Nos. 1221756 and 1279063 are naturally maintained such as the correct pattern recognition can be effected without the affection of the distortion in shape, the shift in position, the expansion or the reduction of the input pattern.

Claims

1. A hierarchical information processing system for processing information in parallel over a plurality of cell layers whereby layers comprising cells that perform similar functions within the layer are organized in successively ordered stages (u_0, u_1, .., u_n), said system comprising:

a plurality of afferent signal paths extending from lower order cell-layers of feature-extracting cells (u_{s-1}) to higher order cell layers of feature-extracting cells (u_{s-n}) with the aid of feature extracting inhibitory cells (u_{sv}) for processing afferent information signals, and

a plurality of efferent signal paths extending from higher order cell layers of feature indicating cells (w_{s-n}) to lower order cell layers (w_{s-1}) for transmitting an efferent signal with the aid of a feature-indicating inhibitory cell (w_{sv}), wherein said feature-extracting cell (u_s) in the afferent signal path is connected to said feature-indicating cell (w_s) in each stage and said feature-extracting inhibitory cell (u_{sv}) is convergingly and modifiably excitatory connected to said feature-extracting cell (u_s) in the same stage and said feature-indicating inhibitory cell (w_{sv}) is modifiably inhibitory connected from said feature-indicating cell (w_s) to divergingly connect to the next lower stage feature-indicating cell (w_{s-1}),

characterized in that:

said afferent signal path comprises a first feature-integrating cell (u_{co}) in the lowest stage and a pair of a feature-extracting cell (u_s) and a

feature-integrating cell (u_c) in each higher stage and the highest stage is connected to a maximum detector;

said efferent signal path comprises a pair of an integrative feature-indicating cell (w_c) and a feature-indicating cell (w_s) in each stage and the integrative feature indicating cell (w_c) of the highest stage is connected to said maximum detector, and the lowest stage consists of the integrative feature-indicating cell (w_c) and each integrative feature-indicating cell (w_c) in each stage is connected to the corresponding feature-integrating cell (u_c) in each stage, wherein said efferent signals are controlled by a plurality of integrative feature-indicating cells (w_c) and feature-indicating cells (w_s) alternatively and divergingly, whereby each integrative feature-indicating cell (w_c) provides paths to a plurality of feature-indicating (w_s) cells in the same stage, each group of said two pluralities of integrative feature-indicating (w_c) and feature-indicating (w_s) cells corresponding to one stage of said stages;

cell layers in each stage, except input-cell layer (u_o) of the lowest stage, having converging afferent connections from feature-extracting cells (u_s) to featureintegrating cells (u_c) and diverging efferent connections from an integrative feature-indicating cell (w_c) to feature indicating cell (w_s);

wherein each feature-extracting cell (u_s) is connected to send an unmodifiable excitatory signal or gate signal to the corresponding feature-indicating cell (w_s) within the same stage, and each integrative feature-indicating cell (w_c) is connected to send a gain control signal to a corresponding feature-integrating cell (u_c) within the same stage, and the transmission of efferent signals is gated by the afferent signals in the feature-indicating cell (w_s), and simultaneously, the transmission of afferent signals is facilitated by the presence of the efferent signals in the integrative feature-indicating cell (w_c) whereby contributive ones of the efferent signal paths are being affected by an excitatory effect, while non-contributory ones thereof are being affected by an inhibitory effect;

whereby a pattern corresponding to the cell which is yielding the largest output among the feature-integrating cells (u_c) of the highest stage is interpreted as recognized; and the output of the integrative feature-indicating cells (w_{co}) of the lowest stage being interpreted as the output of associative recall or as the result of segmentation of a single pattern which is now being recognized.

2. A hierarchical information processing system for processing information in parallel over a plurality of cell layers according to claim 1, characterized by

a threshold controlling cell (w_{cx}) for receiving signals from the integrative feature-indicating cell (w_c) via unmodifiable excitatory connections and receiving converging signals from the feature-extracting cells (u_s) in the same stage and controlling the selectivity for extracting particular features by said feature-extracting cells (u_s).

3. A hierarchical information processing system for processing information in parallel over a plurality of cell layers as defined in claim 2, characterized by said inhibiting cell (u_{sv}) convergingly receiving a pattern signal from the said feature-integrating cells (u_c) of the preceding stage and sending output signals via modifiable inhibitory connections to the said feature-extracting cell (u_s), in the same stage.

4. A hierarchical information processing system for processing information in parallel over a plurality of cell layers as defined in claim 2 or 3, characterized by said feature-indicating inhibitory cell (w_{sv}) being connected to the feature-indicating cell (w_s) in the same stage and being connected divergingly and unmodifiably to the integrative feature-indicating cell (w_c) in the lower stage.

5. A hierarchical information processing system for processing information in parallel over a plurality of cell layers as defined in any of claims 2 to 4, characterized in that it further comprises feedback means for transmitting a signal (x) derived from a maximum detector when no output is derived from any of the feature-integrating cells (u_c) of the highest stage so as to lower the selectivity of each target feature-extracting cell (u_s).

6. A hierarchical information processing system for processing information in parallel over a plurality of cell layers as defined in claim 2, characterized in that the afferent signal path of the feature-integrating cell (u_c) and the feature extracting cell (u_s) and the efferent signal path of the integrative feature-indicating cell (w_c) and the feature-indicating cell (w_s) are interconnected so as to affect said efferent signal by gain control signal from integrative feature-indicating (w_c) cell and to affect efferent signal by gate signal from feature-extracting (u_s) cell to feature-indicating (w_s) cell; and the feature-extracting cell (u_s) is affected by feedback sig-

nal (x) from a maximum detector in the highest stage, and the integrative feature-indicating cell (w_c) is affected by an unmodifiable inhibitory signal from the feature-indicating inhibitory cell (w_{sv}) activated by feature-indicating cell (w_s).

Patentansprüche

1. Hierarchisches Informationsverarbeitungs-System zur parallelen Verarbeitung von Informationen über eine Vielzahl von Zellschichten, wobei Schichten, die Zellen umfassen, welche innerhalb der Schicht ähnliche Funktionen durchführen, in aufeinanderfolgenden geordneten Stufen (u_0, u_1, ... u_n) organisiert sind, wobei das System umfaßt:
   - eine Vielzahl von afferenten Signalpfaden, die sich mittels Merkmalsextraktions-Sperrzellen (u_{sv}) zwischen Zellschichten niedrigerer Ordnung mit Merkmalsextraktionszellen (u_{s-1}) und Zellschichten höherer Ordnung Merkmalsextraktionszellen (u_{s-n}) zur Verarbeitung von afferenten Informationssignalen erstrecken; und
   - eine Vielzahl von efferenten Signalpfaden, die sich mit Hilfe von Merkmalsanzeige-Sperrzellen (w_{sv}) zwischen Zellschichten höherer Ordnung mit Merkmalsanzeigezellen (w_{s-n}) und Zellschichten niedriger Ordnung mit Merkmalsanzeigezellen (w_{s-1}) zum Übertragen eines efferenten Signals erstrecken, wobei die Merkmalsextraktionszelle (u_s) in dem afferenten Signalpfad mit der Merkmalsanzeigezelle (w_s) in jeder Stufe verbunden ist und die MerkmalsextraktionsSperrzelle (u_{sv}) konvergierend und modifizierbar anregend mit der Merkmalsextraktionszelle (u_s) in der gleichen Stufe verbunden ist und die Merkmalsanzeige-Sperrzelle (w_{sv}) modifizierbar sperrend mit der Merkmalsanzeigezelle (w_s) verbunden ist, um die Merkmalsanzeigezelle (w_{s-1}) der nächst niedrigeren Stufe divergierend zu verbinden,

   dadurch **gekennzeichnet,** daß:
   - der afferente Signalpfad eine erste Merkmalsintegrationszelle (u_{co}) in der niedrigsten Stufe und ein Paar aus einer Merkmalsextraktionszelle (u_s) und einer Merkmalsintegrationszelle (u_c) in jeder höheren Stufe umfaßt und die höchste Stufe mit einem Maximumdetektor verbunden ist;
   - der efferente Signalpfad ein Paar einer integrierenden Merkmalsanzeigezelle (w_c) und einer Merkmalsanzeigezelle (w_s) in jeder Stufe umfaßt und die integrierende Merkmalsanzeigezelle (w_c) der höchsten Stufe mit dem Maximumdetektor verbunden ist und die niedrigste Stufe aus der integrierenden Merkmalsanzeigezelle (w_c) besteht und jede integrierende Merkmalsanzeigezelle (w_c) in jeder Stufe mit der entsprechenden Merkmalsintegrationszelle (u_c) in jeder Stufe verbunden ist, wobei die efferenten Signale durch eine Vielzahl von integrierenden Merkmalsanzeigezellen (w_c) und Merkmalsanzeigezellen (w_s) alternierend und divergierend gesteuert werden, wobei jede integrierende Merkmalsanzeigezelle (w_c) Pfade zu einer Vielzahl von Merkmalsanzeigezellen (w_s) in der gleichen Stufe vorsieht, wobei jede Gruppe der zwei Vielzahlen von integrierenden Merkmalsanzeige(w_c) und Merkmalsanzeige-Zellen (w_s) einer Stufe der Stufen entsprechen;
   - Zellschichten in jeder Stufe außer der Schicht (u_o) der niedrigsten Stufe für die Eingangszelle konvergierende afferente Verbindungen von Merkmalsextraktionszelle (u_s) mit Merkmalsintegrationszellen (u_c) und divergierende efferente Verbindungen von einer integrierenden Merkmalsanzeigezelle (w_c) mit Merkmalsanzeigezellen (w_s) aufweisen;
   - wobei jede Merkmalsextraktionszelle (u_s) verbunden ist, um ein nicht modifizierbares anregendes Signal oder Torsignal an die entsprechende Merkmalsanzeigezelle (w_s) innerhalb der gleichen Stufe zu senden und jede integrierende Merkmalsanzeigezelle (w_c) verbunden ist, um ein Verstärkungs-Steuersignal an eine entsprechende Merkmalsintegrationszelle (u_c) innerhalb der gleichen Stufe zu senden und die Sendung von efferenten Signalen durch die afferenten Signale in der Merkmalsanzeigezelle (w_s) geschaltet wird und gleichzeitig die Sendung der afferenten Signale durch das Vorliegen der efferenten Signale in der integrierenden Merkmalsanzeigezelle (w_c) erleichtert wird, wobei beitragende Pfade der efferenten Signalpfade durch einen Anregungseffekt beeinflußt werden, während nicht beitragende Pfade davon durch einen Sperreffekt beeinflußt werden;
   - wobei ein Muster entsprechend der Zelle, die den größten Ausgang von den Merkmalsintegrationszellen (u_c) der höchsten Stufe hervorbringt, als erkannt interpretiert wird; und der Ausgang der

integrierenden Merkmalsanzeigezellen (w_{co}) der niedrigsten Stufe als der Ausgang eines assoziativen Zurückrufs oder als das Ergebnis einer Segmentierung eines einzelnen Musters interpretiert wird, welches nun erkannt wird.

2. Hierarchisches Informationsverarbeitungs-System zur parallelen Verarbeitung von Informationen über eine Vielzahl von Zellschichten nach Anspruch 1,
gekennzeichnet durch
eine Schwellwert-Steuerzelle (w_{cx}) zum Empfangen von Signalen von der integrierenden Merkmalsanzeigezelle (w_c) über nicht modifizierbare Anregungsverbindungen und zum Empfangen von konvergierenden Signalen von den Merkmalsextraktionszellen (u_s) in der gleichen Stufe und zum Steuern der Selektivität zur Extraktion von besonderen Merkmalen durch die Merkmalsextraktionszellen (u_s).

3. Hierarchisches Informationsverarbeitungs-System zur parallelen Verarbeitung von Informationen über eine Vielzahl von Zellschichten nach Anspruch 2,
dadurch **gekennzeichnet,** daß
die Sperrzelle (u_{sv}) konvergierend ein Mustersignal von den Merkmalsintegrationszellen (u_c) der vorangehenden Stufe empfängt und Ausgangssignale über modifizierbare Sperrverbindungen an die Merkmalsextraktionszelle (u_s) in der gleichen Stufe sendet.

4. Hierarchisches Informationsverarbeitungs-System zur parallelen Verarbeitung von Informationen über eine Vielzahl von Zellschichten nach Anspruch 2 oder 3,
dadurch **gekennzeichnet,** daß
die Merkmalsanzeige-Sperrzelle (w_{sv}) mit der Merkmalsanzeigezelle (w_s) in der gleichen Stufe verbunden ist und divergierend und nicht modifizierbar mit der integrierenden Merkmalsanzeigezelle (w_c) in der niedrigeren Stufe verbunden ist.

5. Hierarchisches Informationsverarbeitungs-System zur parallelen Verarbeitung von Informationen über eine Vielzahl von Zellschichten nach einem der Ansprüche 2 bis 4,
dadurch **gekennzeichnet,** daß
es außerdem eine Rückführungseinrichtung umfaßt, um ein von einem Maximumdetektor abgeleitetes Signal (x) zu senden, wenn kein Ausgang von irgendeiner Merkmalsintegrationszelle (u_c) der höchsten Stufe abgeleitet wird, um so die Selektivität einer Ziel-Merkmalsextraktionszelle (u_s) zu verkleinern.

6. Hierarchisches Informationsverarbeitungs-System zur parallelen Verarbeitung von Informationen über eine Vielzahl von Zellschichten nach Anspruch 2,
dadurch **gekennzeichnet,** daß
der afferente Signalpfad der Merkmalsintegrationszelle (u_c) und der Merkmalsextraktionszelle (u_s) und der efferente Signalpfad der integrierenden Merkmalsanzeigezelle (w_c) und der Merkmalsanzeigezelle (w_s) so verbunden sind, um das efferente Signal durch eine Verstärkungssteuersignal von einer integrierenden Merkmalsanzeigezelle (w_c) zu beeinflußen und um das efferente Signal durch ein Torsignal von einer Merkmalsextraktionszelle (u_s) an die Merkmalsanzeigezelle (w_s) zu beeinflußen; und die Merkmalsextraktionszelle (u_s) durch ein Rückführungssignal (x) von einem Maximumdetektor in der höchsten Stufe beeinflußt wird und die integrierende Merkmalsanzeigezelle (w_c) durch ein nicht modifizierbares Sperrsignal von der durch eine Merkmalsanzeigezelle (w_s) aktivierte Merkmalsanzeige-Sperrzelle (w_{sv}) beeinflußt wird.

Revendications

1. Dispositif de traitement hiérarchique de l'information pour traiter l'information en parallèle sur une pluralité de couches de cellules dans lesquelles les couches comprenant des cellules oui accomplissent des fonctions similaires dans la couche sont organisées en étages ordonnés successivement (Uo,U1,...,Un), ledit dispositif comprenant:
une pluralité de voies de signaux afférents s'étendant à partir des couches de cellules du rang le plus bas des cellules d'extraction de caractéristique (Us-1) vers les couches de cellules du rang le plus élevé des cellules d'extraction de caractéristique (Us-n) avec l'aide de cellules d'inhibition d'extraction de caractéristique (Usv) pour traiter les signaux d'information afférents, et
une pluralité de voies de signaux efférents s'étendant des couches de cellules indicatrices de caractéristique (Ws-n) de plus haut rang vers des couches de cellules indicatrices de caractéristique (Ws-1) de plus bas rang pour transmettre un signal efférent avec l'aide d'une cellule d'inhibition indicatrice de caractéristique (Wsv), dans lequel ladite cellule d'extraction de caractéristique (Us) dans la voie du signal afférent est connectée à ladite cellule indicatrice de caractéristique (Ws) dans chaque étage et ladite cellule d'inhibition d'extraction de caractéristique (Usv) est connectée de manière excitatoire convergente et modifiable à ladite cellu-

le d'extraction de caractéristique (Us) dans le même étage et ladite cellule d'inhibition indicatrice de caractéristique (Wsv) est connectée de manière inhibitoire et modifiable de ladite cellule indicatrice de caractéristique (Ws) à connecter de manière divergente à la cellule indicatrice de caractéristique (Ws-1) de l'étage immédiatement inférier,

caractérisé en ce que:

ladite voie de signal afférent comprend une première cellule d' intégration de caractéristique (Uco) dans l'étage le plus bas et une paire de cellule d'extraction de caractéristique (Us) et une cellule d'intégration de caractéristique (Uc) dans chaque étage plus éleva. et l'étage le plus élevé est connecté à un détecteur de maximum;

ladite voie de signal efférent comprend une paire de cellule d'intégration indicatrice de caractéristique (Wc) et une cellule indicatrice de caractéristique (Ws) dans chaque étage et la cellule d'intégration indicatrice de caractéristique (Wc) de l'étage le plus élevé est connectée audit détecteur de maximum, et l'étage le plus bas est constitué de la cellule d'intégration indicatrice de caractéristique (Wc) et chaque cellule d'intégration indicatrice de caractéristique (Wc) dans chaque étage est connectée à la cellule correspondante d'intégration de caractéristique (Uc) dans chaque étage, dans lequel lesdits signaux efférents sont commandés par une pluralité de cellules d'intégration indicatrices de caractéristique (Wc) et de cellules indicatrices de caractéristique (Ws) de manière alternative et divergente, si bien que chaque cellule d'intégration indicatrice de caractéristique (Wc) fournit des voies à une pluralité de cellules indicatrices de caractéristique (Ws) dans le même étage, chaque groupe desdites deux pluralités de cellules d'intégration indicatrices de caractéristique (Wc) et indicatrices de caractéristique (Ws) correspondant à un étage desdits étages;

des couches de cellules dans chaque étage, à l'exception de la couche de cellules d'entrée (Uo) de l'étage le plus bas, ayant ces connexions afférentes convergentes à partir des cellules d'extraction de caractéristique (Us) vers les cellules d'intégration de caractéristique (Uc) et des connexions efférentes divergentes à partir d'une cellule d'intégration indicatrice de caractéristique (Wc) vers une cellule indicatrice de caractéristique (Ws) ;

dans lequel chaque cellule d'extraction de caractéristique (Us) est connectée pour envoyer un signal excitateur non modifiable ou un signal de porte à la cellule indicatrice ce de caractéristique (Ws) correspondante à l'intérieur du même étage, et chaque cellule d'intégration indicatrice de caractéristique (Wc) est connectée pour envoyer un signal de commande de gain vers une cellule d' intégration de caractéristique (Uc) correspondante à l'intérieur du même étage, et la transmission des signaux efférents est passée par une porte par les signaux afférents dans la cellule indicatrice de caractéristique (Ws), et simultanément, la transmission des signaux afférents est facilitée par la présence des signaux efférents dans la cellule d'intégration indicatrice de caractéristique (Wc) si bien que celles des voies des signaux efférents qui contribuent sont affectées par un effet d'excitation, tandis que celles qui ne contribuent pas sont affectées par un effet d'inhibition;

si bien qu'un canevas correspondant à la cellule qui donne la plus grande sortie parmi les cellules d'intégration de caractéristique (Uc) de l'étage le plus élevé est interprété comme reconnu; et la sortie des cellules d'intégration indicatrices de caractéristique (Wc) de l'étage le plus bas est interprétée comme la sortie de la mémoire de rappel associative ou comme le résultat de la segmentation d'un canevas unique qui est en train d'être reconnu.

2. Un dispositif de traitement hiérarchique de l'information en parallèle sur une pluralité de couches de cellules selon la revendication 1, caractérisé par

une cellule de commande de seuil (Wcx) pour recevoir des signaux depuis la cellule d'intégration indicatrice de caractéristique (Wc) à travers des connexions d'excitation non modifiables et recevant des signaux convergents depuis les cellules d'extraction de caractéristique (Us) à l'intérieur du même étage et commandant la sélectivité pour l'extraction de caractéristiques particulières par lesdites cellules d'extraction de caractéristique (Us).

3. Un dispositif de traitement hiérarchique de l'information en parallèle sur une pluralité de couches de cellules selon la revendication 2, caractérisé par ladite cellule d'inhibition (Usv) recevant de manière convergente un signal ce canevas depuis lesdites cellules d'intégration de caractéristique (Uc) de l'étage précédent et envoyant des signaux de sortie à travers des connexions d'inhibition modifiables vers ladite cellule d'extraction de caractéristique (Us) à l'intérieur du même étage.

4. Un dispositif de traitement hiérarchique de l'information en parallèle sur une pluralité de couches de cellules selon la revendication 2 ou 3,

caractérisé en ce que ladite cellule indicatrice de caractéristique (Wsv) est connectée à la cellule indicatrice de caractéristique (Ws) à l'intérieur du même étage et est connectée de manière divergente et non modifiable à la cellule d'intégration indicatrice de caractéristique (Wc) dans l'étage inférieur.

5. Un dispositif de traitement hiérarchique de l'information en parallèle sur une pluralité de couches de cellules selon l'une des revendications 2 à 4, caractérisé en ce qu'il comprend, en outre, des moyens de contre-réaction pour transmettre un signal (x) dérivé d'un détecteur de maximum lorsqu'aucune sortie n'est dérivée de l'une des cellules d'intégration de caractéristique (Uc) de l'étage le plus élevé de manière à abaisser la sélectivite, de chaque cellule cible d'extraction de caractéristique (Us).

6. Un dispositif de traitement hiérarchique de l'information en parallèle sur une pluralité de couches de cellules selon la revendication 2, caractérisé en ce que la voie du signal afférent de la cellule d'intégration de caractéristique (Uc) et de la cellule d'extraction de caractéristique (Us) et la voie du signal efférent de la cellule d'intégration indicatrice de caractéristique (Wc) et la celle indicatrice de caractéristique (Ws) sont interconnectées de manière à affecter ledit signal efférent par un signal de commande de gain depuis la cellule d'intégration indicatrice de caractéristique (Wc) et pour affecter le signal efférent par un signal de porte de la cellule d'extraction de caractéristique (Us) vers la cellule indicatrice de caractéristique (Ws) ; et la cellule d'extraction de caractéristique (Us) est affectée par le signal de contre-réaction (x) provenant d'un détecteur de maximum dans l'étage le plus élevé, et la cellule d'intégration indicatrice de caractéristique (Wc) est affectée par un signal inhibiteur non modifiable provenant de la cellule d'inhibition indicatrice de caractéristique (Wsv) activée par une cellule indicatrice de caractéristique (Ws).

FIG.1

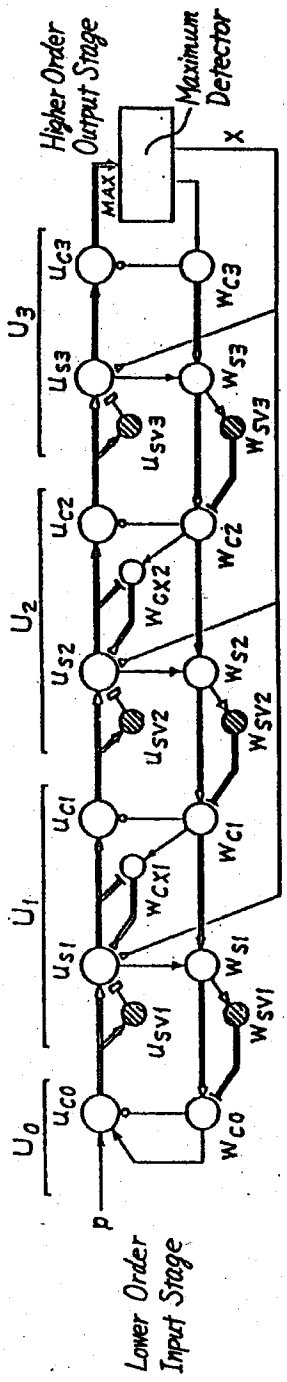
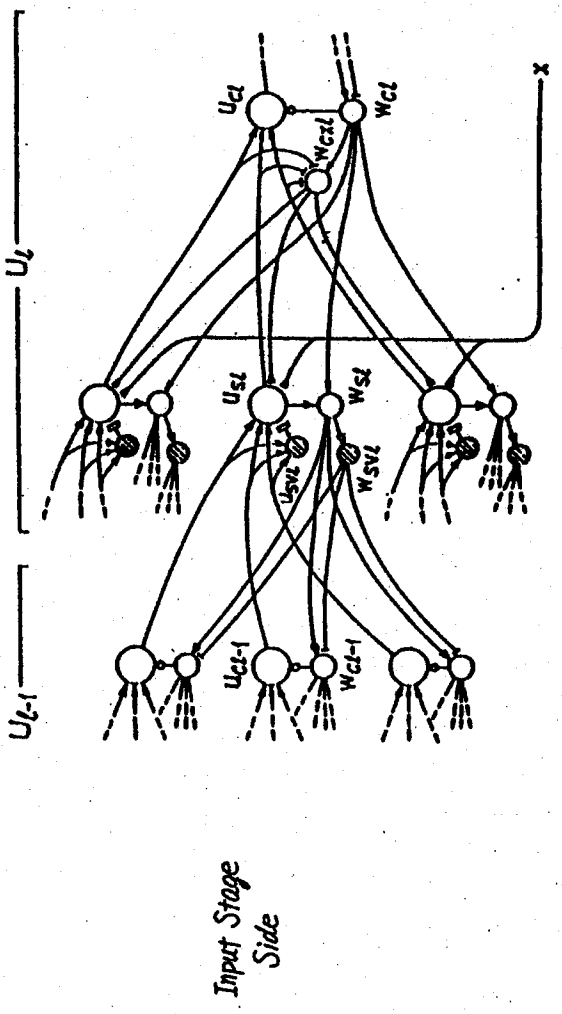

Higher Order Output Stage
Maximum Detector
MAX
x
U_3
U_2
U_1
U_0
u_{C3}
u_{S3}
u_{SV3}
w_{C3}
w_{S3}
w_{SV3}
u_{C2}
u_{S2}
u_{SV2}
w_{CX2}
w_{C2}
w_{S2}
w_{SV2}
u_{C1}
u_{S1}
u_{SV1}
w_{CX1}
w_{C1}
w_{S1}
w_{SV1}
u_{C0}
w_{C0}
p
Lower Order Input Stage

FIG.2


Output Stage Side
U_l
U_{l-1}
u_{Cl}
w_{CXl}
w_{Cl}
u_{Sl}
u_{SVl}
w_{Sl}
w_{SVl}
u_{Cl-1}
w_{Cl-1}
x
Input Stage Side